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Before the Federal Communications Commission
Washington, DC

In The Matter of	)	
Amendment of the Amateur Service	)	
Rules to Provide For	)	WT Docket No. 97-12
Greater Use of Spread	)	
Spectrum Communication	)	RM-8737
Technologies	)	

Comments of Philip R. Karn, Jr, KA9Q

Introduction

I respectfully offer these comments to the Commission in support of the proposed liberalization of the existing rules to permit expanded use of spread spectrum (SS) communications in the Amateur Radio Service. While I am a member of the ARRL Future Services Committee and an employee of Qualcomm Incorporated, a major developer and manufacturer of commercial digital spread spectrum cellular telephone equipment, the opinions expressed here are strictly my own.

Spread spectrum has become an important communication technology. The many advantages of this technique include:

- improved resistance to multipath propagation, especially in urban environments;
- increased resistance to interference, both intentional and unintentional;
- reduced average transmitter power requirements, when combined with error control coding and automatic transmitter power control;
- increased spectrum capacity, especially when carrying intermittent traffic;
- special features, such as accurate ranging

But spread spectrum is, so far, almost entirely a non-amateur phenomenon. While many license-free devices incorporating spread spectrum have been used under Part 15.247 rules, and while the large scale deployment of CDMA (spread spectrum) digital cellular telephones is now underway, use of spread spectrum under the existing amateur rules remains almost nonexistent.

Why Amateur SS Has Failed

The reasons for this include restrictive rules, the lack of suitable equipment and resistance from certain elements of the amateur community. Also, the ready availability of Part 15.247 equipment to amateurs has significantly diluted potential interest in spread spectrum operations under Part 97 rules. Not only are the Part 15 rules far more liberal in the allowed modulation methods and spreading codes, but Part 15 operation also permits encryption and commercial use -- two practices prohibited under amateur rules -- yet, ironically, the Part 15.247 bands are shared with the amateur service. In any event, it is safe to say that far more amateurs are presently conducting spread spectrum operations under Part 15.247 than under Part 97 rules.

But Part 15.247 devices are invariably proprietary "black boxes" designed for ease of use by a nontechnical consumer. While they are quite useful to amateurs (and others) in a "utility" mode (e.g., as Internet access links) Part 15 was not intended to further the basis and purposes of the Amateur Service.

The Amateur Service Needs Maximum Rule Flexibility

The amateur service needs its own spread spectrum rules specifically designed to promote the basis and purposes of the service, particularly technical experimentation, development and self-training. This is best accomplished with an absolute minimum of restrictive regulation, deferring as much as possible to the amateur community to produce its own operating standards and practices to minimize harmful intra-service interference.

The FCC's rules should therefore go no further than to set a maximum transmitter power level and to set limits on spurious emissions outside the amateur bands. In the context of the present proceeding, therefore, the Commission should permit spread spectrum operations on *all* amateur bands, including HF, not just those above 50 MHz or 219 MHz.

Conventions regarding *all* other parameters, including operating frequencies, modulation type, bandwidths, protocols, etc, are best left to the amateur community, as it can react to changing needs and local conditions far more rapidly than the Commission.

HF spread spectrum is particularly interesting, given its inherent ability to deal with interference and ionospheric multipath. Even without full-blown spreading, relaxing the existing bandwidth limits on HF digital modes would permit the use of more power-efficient modulation and coding schemes that could easily permit transmitter power reductions of 10-15 dB or more for a given data rate. Such gains have already been demonstrated by lab and field tests published in QEX that compared military standard HF digital modems operating in 3 KHz channels with those designed within the amateur community for the arbitrarily narrow 500 Hz data channel. A general reduction in average amateur HF transmitter power levels is clearly a desirable goal.

Intra-Amateur Interference Issues

The complete deregulation of amateur spread spectrum may seem like a radical suggestion that would lead to anarchy on the ham bands. Yet the existing FCC rules technically permit many things that, if widely practiced, would also lead to anarchy on the ham bands. For example, there are no specific prohibitions in the rules against

- Operating local FM simplex on the input of a repeater;
- Conducting high power terrestrial DX operations on the downlink of an amateur satellite;
- Conducting local operations on the various EME and DX calling frequencies;
- Operating 100 KHz bandwidth digital links on the 432.1 MHz weak signal calling frequency;

And so on. Despite some well-publicized exceptions, interference of this kind is actually quite rare. There is still a strong sense of community within the amateur service and a willingness to work together to avoid interfering with one's fellow ham.

Even if the rules were amended to permit spread spectrum on all amateur bands, other rules would continue to apply with full force, such as 97.313 (no more power than required to maintain communications), 97.101(c) (priority given to emergency operations) and 97.101(d) (no malicious interference). And the present rules would make spread spectrum operations secondary to other operations.

It is impossible to say that under absolutely no circumstances could spread spectrum operations interfere with traditional narrow band operations. But it is wholly inappropriate to demand such guarantees in the first place. Yes, amateur frequencies are still occasionally involved in emergency communications despite being almost completely eclipsed in recent years by cellular phones, portable satellite links and the like. But the amateur service has *always* been primarily an experimental, technically-oriented service. It is not a critical operational safety-of-life service like public safety or aviation, nor is it a common carrier utility like cellular telephones. Some level of unintentional interference is therefore to be expected and tolerated.

Discussion of the Proposed Rules

I generally support the rules proposed by the Commission with the following exceptions and additions:

Increase the maximum power allowed for SS emissions directed to space

100W is probably enough for any conceivable terrestrial spread spectrum operation, particularly if strong error-control-coding techniques are incorporated to improve the power efficiency of the communication over traditional narrow band signal formats.

But the 100W limit may present a problem for certain promising deep-space applications of spread spectrum, particularly EME (Earth-Moon-Earth) operation with the moon as a passive reflector. The EME link is characterized by severe multipath, making spread spectrum a highly promising technique. The high antenna gains and skyward-pointing antennas generally used with EME clearly make the 100W limit unnecessary to protect terrestrial operations.

Another promising use for high power SS transmissions is communications with interplanetary spacecraft. Discussions are already underway within AMSAT for an amateur-built spacecraft to be flown to Mars, and it would be beneficial to use high power SS transmissions for accurate ranging measurements over interplanetary distances.

I therefore suggest a waiver on the 100W SS power limit for space communications. If the Commission feels it necessary, it could use language similar to that of existing section 97.313(f) to allow use of the waiver only above a certain antenna elevation. (That section specifies that the -3dB point of antenna main lobe be above 10 degree elevation.)

Eliminate the automatic power control requirement

I originally conceived and devised the proposed requirement for automatic transmitter power control with a received Eb/N0 limit. My proposal was adopted by the ARRL Future Systems Committee, of which I am a member, and then by the League in its RM-8737 filing.

I no longer believe this provision should be codified in the FCC rules. It is possible to conceive of situations where it would be difficult or impossible to meet this requirement. The best example is in a multicast situation (one transmitter sending to several receivers simultaneously), where one cannot reach all stations with an acceptable signal without exceeding the Eb/N0 at the nearest station. In any event, the provisions of 97.313, particularly paragraph (a) limiting power to the minimum required to maintain communications would still apply, as it does to all amateur communications.

Ways The Amateur Service Can Mitigate SS Interference

The present proceeding addresses the rules the Commission should establish regarding spread spectrum operation, and in my opinion these rules should be kept to an absolute minimum to promote flexibility and self-regulation within the amateur community. Nevertheless, I believe it would be useful to put into the record some of the approaches that could (and should) be used on a voluntary basis to minimize interference.

This is only a partial list, based on my own ideas and experience. Nonetheless, I believe it shows the potential of the amateur service to devise its own effective and novel solutions to mutual interference problems. I'm sure that other amateurs can add substantially to this list.

Automatic power control

Although I no longer feel it should be a mandatory rule, I still firmly believe in the value of automatic transmitter power control and the minimization of receiver Eb/N0 ratios with the strongest available error control coding. Analysis and field tests of SS-CDMA channel capacity performed at Qualcomm and elsewhere conclusively show the close inverse relationship between receiver Eb/N0 and overall system capacity: every 3dB reduction in Eb/N0 ratio translates directly into a 3dB increase (a doubling) of the number of users that can simultaneously share the channel.

I will certainly endeavor to incorporate power control and strong coding into any system I design, and I will strongly encourage other designers to do likewise.

Directional antennas

It almost goes without saying that when a point-to-point link is desired, directional antennas are always helpful in minimizing the amount of energy radiated in directions other than the intended receiver.

Min-power relaying

It is now well established in studies and experiments with self-organizing distributed packet radio networks (e.g., DARPA SURAN) that it is far more efficient, spectrally speaking, to cover significant distances by relaying data across a series of relatively short links at low power than to send it at high power over long links. This approach is straightforward to implement in existing packet network routing algorithms if the "link cost metric" used in the calculations is simply the estimated transmitter energy required to reach the next station. The routing algorithm will then work to minimize the total transmitted energy, summed over all of the nodes in the path, needed to reach a specified destination.

Alternatively, the link metric can be an automatic estimate of the number of neighboring stations that will have to be "jammed" by the present transmitter using whatever power is needed to reach the next hop. I presented a talk on this specific topic at the 1991 ARRL Digital Communications Conference.

Modifications of these techniques can be used to implement multicasting by relaying relatively low power transmissions to each intended receiver across a spanning tree instead of "blasting" the transmission at high power to all the receivers simultaneously.

These techniques clearly work toward minimizing the total interference potential of a spread spectrum packet radio network.

Geographical Bandplans

Amateur bandplans have already established band segments on the basis of geographical region of use rather than modulation mode. This is especially true in the VHF and UHF bands, where segments are set aside for satellite, local utility and terrestrial weak signal DX operations. The local utility segments are further subdivided into repeater input, repeater output and simplex segments. In mountainous areas such as California, the repeater channels are further divided into "high altitude" (wide area) and "low altitude" (local area) coverage. Even on the HF bands, subbands are frequently set aside by convention for "DX windows" to keep them clear of strong local interference.

Geographical bandplans are a highly effective way to mitigate the "near-far problem". Although usually associated with spread spectrum signals, the near-far problem also exists with conventional narrowband methods, because no receiver is perfect at rejecting strong unwanted signals. This is precisely why these plans evolved in the first place.

Much of the interference potential of, say, a local utility SS link to weak signal DX operations can be completely avoided by such plans. Moreover, the DX operators would be free to use wideband SS-like techniques (such as strong error control coding) within the DX segments for their own purposes.

Narrowband Identification of Spread Spectrum Signals

There has been much discussion within the amateur community of the need to identify interfering signals, especially experimental spread spectrum signals for which the necessary demodulation equipment may not be widely available.

It is my opinion that no special ID rules are really needed here. If a spread spectrum signal does interfere with a traditional narrowband user, then by definition it can be heard by that user. Conventional "fox hunting" (direction finding) techniques can then be used to locate the source of the SS interference, just as they have long been used to identify other interference sources, both narrowband and broadband (e.g., power line interference).

It would be possible in some (but not all) SS systems to incorporate a CW ID that could be demodulated by a conventional receiver. There are many ways to do this, including:

- Gating the entire spread emission on and off with Morse Code;
- Injecting a weak discrete spectral component somewhere in the SS emission and gating it with a Morse identifier;
- "Notching" part of the spread emission with a filter that is gated in and out with the Morse ID

Other possibilities exist. Some are much more practical than others with a given type of signal; for example, it's very simple in a Direct Sequence SS signal to inject a small unspread carrier component by unbalancing the spreading mixer. The notching approach could be implemented in a fast frequency hopping system by simply gating the transmitter off whenever it would otherwise transmit in the notch during a "key up" interval of the ID. And so forth.

While such an ID scheme would clearly be desirable, I argue against making it mandatory. I can easily conceive of situations where it would be difficult or impossible to implement, and the chances of causing harmful interference are nonetheless low. The best example would be a very high speed packet radio modem using spread spectrum, where the transmissions are very much shorter than a Morse ID at a reasonable speed.

Furthermore it is vital to avoid an ID requirement that would itself cause interference even when the associated SS emission does not. To this end, if other commenters persuade the Commission to adopt a narrowband CW ID requirement, then the power spectral density of the ID (as measured in a typical narrowband receiver bandwidth, e.g., 3 KHz) should not be any greater than the power spectral density of the spread emission that it identifies.

Local Coordination

A highly effective interference mitigation technique is to simply announce one's intentions to the local amateur community. There are now many ways that local amateurs can communicate on a regular basis, ranging from traditional meetings and newsletters to packet bulletin boards and Internet newsgroups and web pages.

If it were customary to give notice of spread spectrum operations, including transmitter location, modulation type, bandwidth, power levels, antenna patterns, etc, to the local amateur community, then anyone experiencing interference from an unidentified source would know who to ask.

I have conceived of a more automatic and general technique for dynamic local spectrum management based on packet radio. It is a generalization of the "Busy Tone Multiple Access" scheme that has been in the literature for years. Imagine a local community of radio amateurs who, by convention, all monitor a fixed packet radio channel in addition to an operational radio frequency (e.g., a DX channel on HF). The stations could announce their receive frequencies on the local packet channel, asking others to stay clear. Such a feature could easily be automated, perhaps integrated with the existing APRS (Amateur Packet Reporting System) that displays GPS station location information. Such a system could work to prevent inadvertent local interference between all types of amateur operations, not just those involving spread spectrum.

Conclusion

I again state my very strong support for the Commissions' proposal to liberalize the spread spectrum rules. Spread spectrum operations should be permitted on as many amateur bands as possible, on a secondary basis, subject only to a total power limit (100W, waived for space operations) and to all the other rules governing the use of minimum necessary power, avoidance of intentional interference, and the like.

Concerns about interference to narrowband operations, while not entirely unfounded, are greatly overblown. The amateur service is fundamentally experimental in nature, and interference has long been a fact of life in the amateur service. These issues are best resolved by the good will and cooperation of the amateurs themselves, not inflexible and detailed rules established by the Commission.

Indeed, given the overall industry trend toward more flexible, dynamic and efficient usage of radio spectrum, the creation of effective cooperative procedures for interference mitigation is itself an opportunity for the amateur service to contribute significantly to the state of the radio art.

Respectfully submitted

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